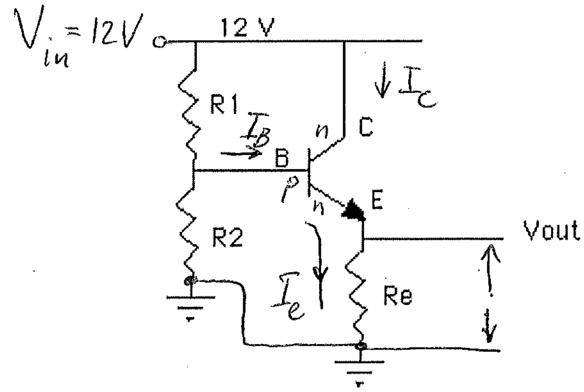
Comments for transistor circuits in Lab. 4. 02/20/17



I_B - base current;
I_c - collector current;
I_e - emitter current;

$$\beta \equiv \frac{I_c}{I_B} \approx \frac{I_e}{I_B} >>> 1.$$

$V_{in} = 12V$ is dc input.

Fig. 3. Transistor circuit that is supposed to function as a good voltage source, meaning that it should provide more or less fixed output voltage V_{out} (measured across the load resistor R_e), irrespective of the value of the load resistance R_e. NOTE: V_{out} as well as all other voltages are measured or applied with respect to the common ground.

According to the basic transistor properties, the base current must be extremely small compared to the collector and emitter currents, so that the amplification factor β is: $\beta \equiv \frac{I_c}{I_B} \approx \frac{I_e}{I_B} >>> 1$ (typically $\beta \sim 10^3$).

$I_B + I_c = I_e$, $I_c \approx I_e$;

According to the voltage divider equation, base potential is: $V_B = \frac{R_2}{R_1+R_2} \cdot V_{in}$, where $V_{in} = 12\,V$ is a dc input voltage.

Then, $V_{out} \equiv I_e \cdot R_e = \beta I_B \cdot R_e = \beta R_e \cdot \frac{V_B - V_{out}}{r_{be}}$, where

r_{be} is the resistance of the pn-junction biased forward which is very low (r_{be} should be about 10-100 Ω).

Thus, by solving for V_{out} in the equation above, we get:

$$V_{out} = \frac{\beta \cdot \frac{R_e}{r_{be}}}{1 + \beta \cdot \frac{R_e}{r_{be}}} \cdot V_B \simeq V_B = \frac{R_2}{R_1+R_2} \cdot V_{in} \qquad (1).$$

This prefactor remains very close to 1, independently on R_e value, because $\beta >>> 1$ and $R_e/r_{be} >> 1$, which reduces loading effects.

R_L is load resistor.

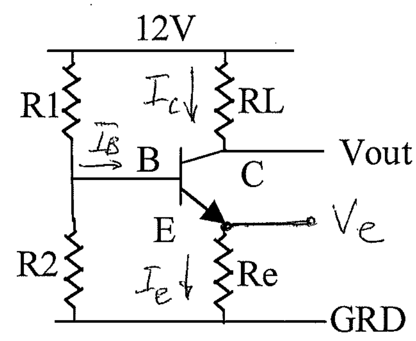


Fig. 4. Transistor circuit that is supposed to function as a good current source, meaning that it should provide more or less fixed collector current (flowing through the load resistor R_L), irrespective of the value of the load resistance R_L. NOTE: V_{out} as well as all other voltages are measured or applied with respect to the common ground.

Here, as always, the transistor is trying to maintain large β, and hence $I_c \approx I_e$. By definition, $I_e \equiv \frac{V_e}{R_e}$.

At the same time (see prev. page): $I_e = \beta I_B = \beta \cdot \frac{V_B - V_e}{r_{be}}$.

Hence, for V_e, we get: $V_e = \frac{\beta V_B \cdot R_e}{\beta R_e + r_{be}}$.

And for I_e, we get: $I_e \equiv \frac{V_e}{R_e} = \frac{\beta V_B}{\beta R_e + r_{be}}$.

But $I_e \approx I_c \equiv \frac{V_{in} - V_{out}}{R_L}$, and hence:

$$\frac{\beta}{r_{be} + \beta R_e} \cdot \frac{R_2}{R_1 + R_2} \cdot V_{in} = \frac{V_{in}}{R_L} - \frac{V_{out}}{R_L} \Rightarrow$$

$$V_{out} = V_{in} \cdot \left(1 - \frac{\beta R_2 R_L}{(R_1 + R_2)\cdot(r_{be} + \beta R_e)}\right),$$ and thus:

$$I_c \equiv \frac{V_{in} - V_{out}}{R_L} = V_{in} \cdot \frac{\beta R_2}{(R_1 + R_2)\cdot(r_{be} + \beta R_e)} \approx V_{in} \cdot \frac{R_2}{(R_1 + R_2)\cdot R_e}, \quad (2)$$

$\beta R_e \gg r_{be}$

which is independent of R_L.